

# INCREASED STIFFNESS OF VEHICLE STRUCTURE IN ACCIDENT

## CROSS REFERENCE TO RELATED APPLICATIONS

- 5 This is a continuation-in-part application of co-pending international application number PCT/DE 96/02120 filed Nov. 7, 1996 and claiming the priority of DE 19543706 A1 filed Nov. 17, 1995. This PCT/DE 96/02120 (WO 97/18984) is revised and refiled
- 06/03/97 and 07/08/97 for the purpose of amending the drawings, description, claims and contesting the prior art ref. to the German examination report of 09/09/96 and PCT
  - 10 search report of 03/24/97;
  - 12/09/97 in order to correct and list the opposed prior art documents DE-OS 4342038 A1, DE-OS 2162071, U.S. Pat. No 4,307,911 (DE 3103580 A1), U.S. Pat. No. 3,819,228, EP 0423465 A, EP 0642940 A (Patent family member U.S. Pat. No. 5,518,290), EP 0659601 A and DE 3726292 C1 in compliance with the PCT rules ref. to
  - 15 the preliminary PCT examination report of 10/02/97 and
  - 12/07/98 in order to correct and list the opposed prior art documents U.S. Pat. No. 3,788,686, U.S. Pat. No. 3,819,228, U.S. Pat. No 4,307,911, U.S. Pat. No 4,676,524, U.S. Pat. No 5,306,067, U.S. Pat. No 5,806,917, DE-OS 2405875 and DE 4240416 A1 ref. to U.S. examination report of 10/14/98.

The abbreviations DE and EP denote the German Pat. Application or Document and European Pat. Appl. or Doc., which will be omitted hereinafter.

All mentioned Pat. Appls./Docs, a 53-page report to the EU-Commission, US-, Canadian and Japanese Ministries for Transport, all accident reports by newspapers, German Police and the inventor listed in the Chap. "OTHER PUBLICATIONS" are parts of submittal.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention:

The present invention relates generally to vehicle doors and, more particularly, to interengaging assemblies which structurally integrate all vehicle doors, when closed, with

30 the vehicle roof, both side rails (sill portions) arranged along the vehicle floor, all post sections (pillar portions) and the flanges of door apertures of vehicle body (passenger compartment or cell) thereby distributing energy to all those vehicle members, lowering stress thereof, preventing passenger ejection and enhancing survival chance in the event of any collision (front, side and/or rear collision) and/or rollover (overturn).

### 2. Discussion of the Prior Art:

In order to formulate in single terminology a generalized definition for the proper term is presented:

#### Definition:

"series-connected  
doors"

"girder"

#### Proper Term:

doors of one vehicle side are series-connected

panel, shell, beam etc. according to FEM and Technical  
Mechanics

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"window-guide elements" of vehicle doors	window-guides 6, 6B, 6.1, 6.2, 6.1B, 6.2B, 6.1a, 6.2a, 6.1aB, 6.2aB
"door cavity"	space between the outer and inner panel of the door
"door detachment"	vehicle door becomes detached from the vehicle body
"mating parts of interengaging assembly"	mating parts of an interengaging assembly such as key & receptacle, hook & recess, hole & key or hook & rod
"engaging hole"	aperture, slot, oblong hole
"vehicular couple"	two mating vehicle members, such as vehicle door & vehicle roof, vehicle door & side rail, vehicle door & flange (transition region) of vehicle body, vehicle door & post section/s, vehicle door & vehicle door in engagement in the event of any collision and/or rollover

It is known in the prior art to provide interengaging assemblies to engage and/or clamp the vehicle door with the mating vehicle members, when the vehicle door is in closed position, thus distributing energy, lowering stress whilst enhancing survival chance only in the event of either mid-front collision or side collision of type U2, one of four types shown in Fig. 13. However, all these conventional configurations do not take into account the failure of passenger protection due to the following problem cases in conjunction with disengagement of the mating parts of interengaging assemblies from each other in the event of all types of real collision (any real collision) and/or real rollover:

- A Load cases I to V according to Technical Mechanics/FEM in real front, side and rear collision;
- B Wrong assumption of the prior art for the purpose of idealizing a general side energy  $S$  or  $S_1$  to a single energy  $S_x$  or  $S_{x1}$ ;
- C Analogy between the state of non-contact and disengagement;
- D Constant, small contour-clearance and assembly tolerance zones;
- E Large clearances of interengaging assemblies;
- E1 The first inventions of interengaging assemblies, huge production costs and fatal injury in real collision due to large clearances;
- E2 Large deformation of vehicle structure or door 8. 8B in real collision;
- E3 Large deformation of side rail 18 in real collision;
- E4 Large deformation of upper door frame 8.17 and vehicle roof 17 in real collision;
- E5 Intrusion of vehicle roof 17 in vehicle body 20 in real rollovers; and
- E6 Clamping assemblies or adjustable interengaging assemblies to resolve problem case E.

Evidence for failure of the prior art, resulting in door detachment associated with passenger ejection and intrusion of vehicle members and/or power plant (drive assembly) associated with severe/fatal injuries, is listed in the 53-page report [1] for the purpose of minimizing injury-severity level, number of injuries and injury-related costs, over \$ 1 billion per day, in real accidents of vehicles world-wide, some of which, having always achieved very good to best verdicts in the front crash tests, are German and Volvo cars known world-wide as the safest. NHSTA [19] has confirmed the correctness of the theses and commitment therefor.

Problem case A: In order to idealize an impact force  $2F_1$  in Fig. 10A imposed on a vehicle structure the following assumptions must be specified:

- let the vehicle structure be idealized by two symmetric vehicle halves subjected to an front impact force  $2F$  along the centre line.

Load case I in z-y plane in Fig. 5: The moment  $M_x = H \cdot h$  about the x-axis is replaced by a pair of forces  $H_A = (H \cdot h)/l$  with the lever arm of  $l$ . Employing the equilibrium condition for moments two forces of reaction are obtained:  $V_A = (V \cdot l_c)/l$  and  $V_B = -V_A + V$ . Acting in z-direction with respect to the sign are three shear forces:  $-V$ ,  $(H_A + V_A)$  and  $-(H_A + V_B)$ .

Under load of these forces the vehicle side, comprising all post sections, series-connected doors 8, 8B reinforced by impact elements and interengaging assemblies of those doors and post sections, is subjected to the bending moment along the y-axis.

Load case II in z-x plane in Fig. 6: The force  $V$  exerts bending moment  $M_{zx}$  along the x-axis and rotating moment  $M_y = V \cdot b$  about the y-axis acts as torsional moment along the vehicle side.

Load case III in x-y plane in Fig. 7: The A-post section is under load of rotating moment  $M_{xy} = -H \cdot b$ . The vehicle side is subjected to bending moment  $M_{xy}$  along the y-axis and buckling force  $H$ .

Subjected to the total stress of bending moments  $M_{zx}$ ,  $M_{xy}$ ,  $M_{zy}$ , buckling force  $H$  and torsional moments  $M_z$ ,  $M_y$  in the load cases I to III, the vehicle side in Fig. 8 is deformed in real front collision.

By reversibly arranging the series-connected doors 8, 8B the same load cases are obtained for real rear collision.

Load case IV in x-y plane in Fig. 9: Under load of side impact energy  $S$  at impact angle  $\alpha$  27° according to FMVSS 214 or in the event of real side collision the vehicle side is subjected to bending moment  $M_{xys}$  along the y-axis and lateral force  $S_y$ .

Load case V in z-x plane in Fig. 10: Under load of side impact energy  $S$  at impact angle  $\gamma$  or in the real side collision against a tree or highway column 22 in Fig. 10A, 13 the vehicle side is subjected to bending moment  $M_{zxs}$  along the z-axis and lateral force  $S_z$ .

The total stress consists of the stresses in load cases IV and V.

Problem case B: With the exception of DE 4342038 A1, the prior art is governed by the following assumptions:

- let clearances between mating parts of an interengaging assembly be neglected and
- let the load cases IV and V be idealized to a lateral energy  $S_x$  in Fig. 9 or  $S_{x1}$  in Fig. 10A imposing on the centre of vehicle door, illustrated as collision type U1 in Fig. 13, despite four collision types U1 to U4 [15] and the collision type U2 having the highest percentage of severe and fatal injuries. Nevertheless, car manufacturers and suppliers world-wide have adopted this idealized  $S_x$  or  $S_{x1}$  in inventions e.g. U.S. Pat. No. 4,307,911, U.S. Pat. No. 5,806,917, U.S. Pat. No. 5,518,290 (EP 0642940 A, DE 3934524), whose shortcomings are mentioned in the following problem case E2.

Problem case C: As exemplified in [2], reproduced in Figs. 11, 12, both end coils of compression-coil spring 19 are guided by two spring seats 19.1. Their utmost outer nodes  $KN_1$  and  $KN_{End}$  (not drawn) rest against both stops 19.3, where  $i$  represents the number of coils. To survey the rolling behaviour of end coil 19 on the lower spring seat 19.1 the end coil is idealized in elements by supporting springs in reference to the nodes and by the threshold value of the distance in the "state of rolling"  $s < 0.1$  mm. Fig. 12, [2] illustrate the rolling behaviour in regard to the FEM data and test results marked with M in dependence on  $F_z = -790, -1000$  and  $-3000$  N:

- According to test results  $KN_2$  to  $KN_5$  roll on the spring seat at  $F_z = -790$  N, but in the state of non-contact at  $F_z = -1000$  and  $-3000$  N.

- According to FEM data the nodes in the following states are in dependence on  $F_z$ :

$F_z$	State of contact	State of rolling
-100	$KN_1, KN_{15}, KN_{17}$	$KN_1$ to $KN_3, KN_{10}$ to $KN_{18}$
-250	$KN_1, KN_{19}, KN_{20}$	$KN_1, KN_{15}$ to $KN_{23}$
-1415	$KN_1, KN_{17}, KN_{19}, KN_{20},$ $KN_{30}, KN_{31}, KN_{33}, KN_{34}$	$KN_1, KN_{15}$ to $KN_{35}$

When both end coils roll on the mating spring seats upon increase of energy, some nodes/elements thereof, previously in the state of contact, are in the state of non-contact. Analogously, interengaging assemblies are exposed to the disengagement.

Problem case D: Recently in automotive industry, great efforts have been made to achieve (finish) a constant (uniform), small contour clearance [16] between the outer door-contour "abcde" of vehicle door 8, 8B and the door aperture of vehicle body 20 in Fig. 5. in order to minimize flow noise and, particularly, to achieve sales success in co-operation with an overall impression of attractive design. In the state of assembly the contour clearance e.g. of AUDI ® vehicles is only 2.5 mm and of VW Passat ® 3.5 mm, 0.5 mm less than Japanese vehicles according to VW CEO Dr. Piëch [17].

For the purpose of automatic assembly with the above-mentioned goal, a device ref. to DE 3726292 C1 determining six reference points on the outer door-contour calculates the differences between the outer door-contour and the door aperture (opening) of vehicle body 20 within the assembly tolerances by assembly, disassembly and assembly of the same vehicle door in Fig. 18.

Problem case E: The position  $D_1$  of door lock 248, rigidly attached to vehicle door 8, and the position  $B_1$  of striker 298, rigidly attached to post section illustrated as B-post section in Fig. 10A of U.S. Pat. No 4,307,911 representing the prior art, is provided with locking clearances in x-, y- and z-direction, thus ensuring the state of door locking and the normal operation of vehicle door. For the purpose of preserving the constant, small contour-clearance,

- the position  $D_a$  to  $D_c$  of each key 128a to 128c, rigidly attached to vehicle door 8, and the position  $S_a$  to  $S_c$  of mating receptacle 158a to 158c, rigidly attached to lower stiff panel 156 of side rail 18;

- the position  $D_n$  of key 148, rigidly attached to vehicle door 8, and the position  $B_n$  of mating receptacle 198, rigidly attached to post section,

must be provided with position-tolerances, larger than locking and assembly tolerances, in x-, y- and z-direction in order to avoid

1. interference with the locking operation of door lock 248 to striker 298 when closing vehicle door 8;

2. expensive reworking at the assembly line;

3. customer complaints due to disturbing noises [3]. Due to the small distances of overlaying coils denoted as  $w \leq 0.2$  mm in Fig. 11, noises such as rattle etc. [3] occur at different oscillations when driving. This condition is comparable with the distances of the mating parts of interengaging assemblies to each other; and

- 5 4. high reject rate due to different references of coordinate system of vehicle door, finished by two to three suppliers and transported to assembly line, and of vehicle body 20, finished at the assembly line. Huge costs are necessary to computerize design data of vehicle door and structure in data files, which must be evaluated by innovative programs to minimize those position-tolerances and reject rate, however, under the condition of  
10 the constant, small contour-clearance.

Noteworthy: A pin, in free connection with a king-size hole, under load can never engage therewith due to large tolerance. A prerequisite for engagement is small tolerances (clearance) of mating parts in x-, y- and z-direction. Examiners of German and European Patent Office as well German and European engineers  
15 classify such engagement or connection governed by small tolerances as form-locking connection.

Problem case E1: According to the first invention of the largest German Corp. having over 100 years of experiences of building luxury cars ref. to DE-PS 1755611 of 06/06/68, the taper-formed key 148 and the mating receptacle 198 should be in engagement or form-  
20 locking connection ("Verbindung" in Claim 1) to ensure energy-transmission from one post section to the other.

Because receptacle 198 and striker 298 are formed together in one piece, an adjustment of receptacle 198 changes the position of striker 298 to the door lock 248 as well as the clearance therebetween, which becomes too large or small. In order to properly latch and  
25 lock the vehicle door to vehicle structure the "interengaging" assembly is provided with large tolerance zones, thus violating the condition of the aforementioned feature.

When a luxury vehicle [11] of this Corp. driven on a slippery icy road laterally crashed against a truck, the key 148 disengaged from mating receptacle 198 due to large clearance so the remaining energy totally deformed the vehicle door, whose intrusion fatally injured  
30 the driver.

At the end of the 80's the Corp. decided to stop the production of over 20 million "interengaging" assemblies, wherewith over five-million vehicles had been equipped within two decades. A problem of two tolerance zones remains unresolved and is very costly.

According to the second invention of the 2nd largest Japanese car Corp. ref. to DE-OS  
35 2162071 of 07/06/72 in Fig. 1A, contour tongues 16.1 should be in engagement with contour grooves 16.2 in order to integrate vehicle door 8, 8B into side rail 18, vehicle roof 17 and B-post section in side collision. Without "interengaging" assembly of the vehicle door and B-post section, the normal operation of vehicle door would be possible if the outer door-contour "abcde" were square. Regarding the recent contour design in Figs. 5 and 18  
40 the line "ab" is generally curve-shaped, line "bc" of front door upwardly inclined ( $\beta > 90^\circ$ ) or generally curve-shaped and line "bc" of rear door generally S-shaped, so contour grooves 16.2 would interfere with contour tongues 16.1 when closing the vehicle door.

Furthermore, to sustain large impact energy it is necessary to reinforce the wide contour groove by an element which, unfortunately, can't be attached to the narrow upper region of  
45 door frame 8.17.

If this invention were really useful, why had the Corp. not implemented it in each of two sport utility vehicles, whose vehicle structure collapsed and steering column intruded into vehicle body 20, in 40 % offset crash test [1] at low speed of 50 km/h conducted by ADAC?

According to the first U.S. Pat. No. 3,819,228 of the largest Italian car Corp. of 06/25/74 a bulky "engaging" bolt rigidly attached to a stiff inner panel of vehicle door 8 projects through a hole of a stiff element attached to side rail 18 when the door is in closed position. The problem of large tolerance zones remains unresolved. Moreover, the overall stylish impression spoilt by a bulky "engaging" bolt will, doubtless, not be beneficial to sales. When stepping in or out of the vehicle body while cleaning or repairing, the person can injury himself when stumbling over this bulky bolt. When closing the door the danger of damage to clothing and injury to passengers, particularly when it is dark, is apparent. If this invention were really useful, why had the Corp. not implemented it in the latest compact car, whose vehicle structure collapsed in a real front collision [14] and in 50 % offset crash test [1] at low speed of 55 km/h conducted by Auto Motor und Sport, wherein the femur force of 15100 N would fracture both legs?

Problem case E2: Both luxury cars [6, 7], a convertible car [10], U.S. Pat. No. 5,518,290 (EP 0642940, DE 4330620) and U.S. Pat. No. 4,676,524, which are described in this Chap., belong to a well-known car manufacturer having HQ in South Germany.

All four passengers, where one of them was instantly dead at the accident site, were hurled out of a brand-new luxury car [6] colliding into a tree in Wiesbaden City and rolling over. Under load of force  $F_1$  in Fig. 10A the deformation of vehicle structure, particularly in y-direction, was larger than that of each vehicle door whose catching hook 148, rigidly attached to impact beam 1, 1B, and door lock 248 were disengaged from the mating recess 198 and striker 298, all of which were arranged to post section.

In a real side collision of another luxury car [7] of the same car manufacturer into a tree, great energy totally deformed the vehicle side whose intrusion fatally injured both passengers. Obviously, the lateral force, deviating from the idealized force  $S_{X1}$ , could not force catching hook 148 to penetrate into recess 198 in order to define an "interengaging" assembly ref. to U.S. Pat. No. 5,518,290.

Both real accidents resulting in severe/fatal injuries verify the shortcomings of any patent valid only for survival chance under load of an idealized force  $S_{X1}$ , denoted by arrow A in Fig. 1 of U.S. Pat. No. 5,518,290. Taken as given, the mid region of door is secured to the B-post section by the "interengaging" assembly in an "idealized" accident, the upper, lower door frame 8.17, 8.18, the vehicle roof 17 and side rail 18 are overstressed due to lack of interengaging assemblies. Moreover, problem cases E3 to E6 remain unresolved.

As exemplified by U.S. Pat. No. 4,676,524, a pair of vertically supporting window-columns, rigidly mounted in both vehicle doors 8 of a convertible car is in abutting, "engaging" relationship with both termini of upper member of cowl, when both vehicle doors are in closed position, owing to a pair of "interengaging" assemblies, each of which consists of

1. a receptacle of the terminus of the upper member and a locking mating tip of key of the window-column pressing therein in the first embodiment; or
2. a king-size hole of the terminus of the upper member and a mating key of the window-column having a mushroom-shaped head being in free connection therewith in the second embodiment

for the purpose of enhancing survival chance in rollover.

When the convertible car rolls over,

1. great shear force fractures each locking tip of key; or
2. great impact energy totally deforms each "interengaging" assembly, whose key and king-size hole are in disengagement ref. to Chap. "Noteworthy", thereby totally deforming the cowl and pair of window-columns.

The stiffness of such open roof of a convertible car [10], merely supported by a pair of post sections in force-locking or free connection with one pair of small-size window-columns, is

- very low, thereby resulting in fatality in a real rollover thereof;
- lower than that of a rotatable, stiff rollover bar ref. to U.S. Pat. No. 5,284,360 (DE 4130470 C1) solely implemented in convertible cars of the largest German Corp.,
- far lower than that of the closed roof 17 supported by two pairs of post sections of the safest sport car [4] ref. to problem case E6 and
- substantially far lower than that of the roof construction according to the invention ref. to DE 4344604 C1 to reinforce the closed roof 17 strongly supported by three pairs of reinforced post sections of the safest, top luxury car [12] whose passengers were instantly dead in a real rollover ref. to problem case E5.

Problem case E3: Due to great energy in a real side collision against column 22 of a central barrier in Fig. 10A, 13 on a highway

- large deformation of side rail 18 and rear section of a brand-new two-seater German top model [5] of the largest European car manufacturer, opposite to x-direction, caused the disengagement of the driver's less deformed vehicle door 8 from vehicle structure and later on
- the vehicle [5] rolled over three times across the highway and down-hill, thus totally deforming vehicle structure, doors 8, tailgate-door 8T, out of which both rear passengers were hurled, and, alternately, opening and closing both vehicle doors 8, out of which both front passengers were hurled out.

Grass 70 clamped between each post section and each vehicle door 8 in Fig. 8 was an evidence for the alternate opening and closing of both vehicle doors 8 during the rollovers.

In a side collision of a small German car [8] into a tree great energy totally deformed vehicle door 8 whose intrusion severely/fatally injured the passengers.

In a collision of another car [9] into a hill great energy totally deformed the right side rail 18 thus resulting in the disengagement of the door lock 248 and, if provided, interengaging assemblies too and later on totally deforming vehicle structure during rollover. The driver was hurled out of this car.

Problem case E4: In front collision or crash test impact energy deforms, in general, upper door frame/s 8.17 outwards and vehicle roof 17 upwards, thereby creating a gap o in Fig. 10A and preventing front vehicle door/s 8, 8B and/or vehicle roof 17 from transmitting energy to vehicle body 20.

Three different states of deformation are reproduced in three crash tests, conducted by ADAC, of the German vehicles of the same type [18] 40 % offset crashed at the same speed of 50 km/h against

- a very stiff barrier,
- a deformable barrier and
- another vehicle of the same type

because the uniform load, deformable property of two colliding masses, impact condition etc. are different. The gap o having three different sizes in Fig. 8 verifies the above-mentioned thesis of non-transmission of energy.

In side collision impact energy deforms, in general, upper door frame/s 8.17 inwards thereby inflicting injuries on head.

Problem case **E5**: During rollover of the top luxury car [12] of the largest German Corp. several times, impact energy totally deformed vehicle roof 17 whose intrusion severely or fatally injured both front passengers, whose heads were, definitely, crushed by falsely deployed airbags, and the remaining energy totally deformed vehicle body 20 and doors 8, 8B, 8T, 8x.

Problem case **E6**: Responsive to problem case **E**, a clamping assembly ("Verkrallungspaar"; "Türverkrallung" = door clamping. "verkrallen" = to clamp) of EP 0423465A1 illustrated in Fig. 1B comprises

- a stiff hook of stiff ledge 25.2 rigidly mounted to lower door frame 8.18 and
- a thin mating panel of a stiff plate 25.1, rigidly attached along sill rail 18, serving as a site of predetermined fracture.

In excess of predetermined value in real side accident, the mating parts 25.1, 25.2 of interengaging assemblies are in the state of clamping to ensure the permanent engagement of lower door frame 8.18 with sill rail 18 in order to resolve the problem of passenger ejection. The proprietor, a German sport-car manufacturer, has built, beyond doubt, the safest sport cars in the world. Load cases **I** to **III**, **V** and problem cases **E2** to **E5** remain unresolved. Furthermore, there is no space to house both mating parts 25.1, 25.2 in vehicle roof 17 and upper door frame 8.17 subjected to lateral load  $F_0$  in real accident. The lack of interengaging assemblies became obvious in the rollover of its classic, very expensive sport car [4], which plunged seven meter downwards and crashed with vehicle roof 17 at a lower level of an underpass in Wiesbaden City thus totally deforming vehicle roof 17, body 20 and both upper door frames 8.17 during rollover, where the remaining energy was transmitted through both head rests, integrated into the respective seatbacks, to the vehicle floor, thereby reducing the AIS of both passengers. AIS is an international acronym of Abbreviated Injury Severity ranging from 0 (no injury) to 6 (fatality).

Responsive to problem case **E**, adjustable and/or latching mechanisms are provided for interengaging assemblies ref. to DE 4342038 A1, whose adjustable and/or latchable keys are bolted to the B- or C-post section, facing the termini of both reinforcing beams 1, 7 or 1B, 7B, and whose mating receptacles are arranged thereto. Both plates 5.1, 5.2 of each hinge of vehicle door are provided with a rivet serving as key and an oblong mating hole. Owing to this feature load cases **I** to **IV** are resolved, but load case **V** and problem cases **E3** to **E5** remain unresolved.

Evidently, due to load cases **I** to **V** and all problem cases **B**, **E**, **E1** to **E5** "interengaging" assemblies of the remaining prior art are unsuitable for the purpose of energy-transmission and distribution by means of the integration of vehicle doors 8, 8B, 8T into the vehicle body 20, such as U.S. Pat. No. 5,297,841 (EP 0659601 A1), U.S. Pat. No. 4,307,911 characterized with five tolerance zones, U.S. Pat. No. 5,806,917, whose priority date of Dec. 22, 1995 is six weeks later than this present invention, characterized with eight tolerance zones.

Upon reading the report [1] examiners, inventors and accident-experts can perceive the relationship of failure of passenger protection with deficiencies of the remaining prior art.

## SUMMARY OF THE INVENTION

Accordingly, the principle object of the present invention is to overcome the deficiencies of the prior art by providing engagement for interengaging assembly having large clearances, which are necessary in car manufacturing and door assembly, in order

- to protect passengers against ejection from the vehicle body and/or intrusion of vehicle member and
- to increase the vehicular stiffness

in the event of any collision and/or rollover. These interengaging assembly are arranged to the corresponding vehicular couples (vehicle member & mating vehicle member).

This principle and other objects of the present invention are accomplished by the following features (proposals):

- minimum tolerances by installing and adjusting the engaging keys from outside to tightly mate the receptacles thereby ensuring the connection of the doors with all vehicle members of vehicle body 20 such as post sections, vehicle roof 17, flange 21, a pair of side rails 18, fastened to vehicle floor, in any collision and/or rollover;
- interengaging assemblies with adjusting mechanisms such as holes & keys 15.1 to 15.5a, 15.7, 15.8, hooks 15.6 & reinforcing rod 17.1d and holes & keys 30 to 37 in Fig. 1, 3, 3A, 4, 4A and 14 to 18;
- window-guide elements to accommodate the engaging parts;
- space-saving, inexpensive design for engaging parts;
- arrangement of interengaging assemblies of a vehicular couple in at least two operating planes thus making the strict restriction of minimum tolerances less significant;
- arrangement of an U-shaped extension member having keys in the common post section of the series-connected vehicle doors, whose holes mate with the keys to ensure the engagement owing to constrained deformation thereof.

Despite the failure of the prior art in the event of real side collision any modification and extra design for survival chance in real collision and/or rollover will generate costs, R&D expenses and weight due to the use of other inventions.

Summary of the advantages of the present invention:

A) saving labour-time by installing and adjusting engaging parts from outside the vehicle body.

B) low reject rate.

C) space-saving, inexpensive design.

D) dissimilar operating planes or at least two operating planes for each vehicular couple to ensure the engagement of its interengaging assemblies in association with energy absorption due to load cases in three different planes. Figs. 14 to 18 illustrate *a single vehicular couple*: window-guide element & B-post section with the interengaging assembly: keys 34 & holes in z-x plane acting as the first operating plane, however, interengaging assemblies: keys 32, 33 & holes in z-y plane acting as the second operating plane. The specification is changed from the minimum tolerances of "narrow" to permissible tolerances of "far less narrow", thus cutting costs and time associated with less adjustment work to reduce large clearances thereto. This feature of dissimilar operating planes is applicable too for both interengaging assemblies: holes & 15.1, 15.2a and 15.2, 15.3 and 15.4a, 15.5 etc. in Fig. 3. A row of the same keys is operative in dissimilar operating planes by arranging a number of the same keys 15.1 to the generally inclined A-post section or of keys 33 to the generally inclined B-post section. In reference to the global xyz coordinate system the key 15.2a & hole is operative in an inclined plane.

Because the hinge bolts of the front and rear doors have an operating direction in z-axis the arrangement of interengaging assemblies: holes & keys 31, 36 to one operating plane is sufficient. However, any additional arrangement of holes & keys 30, 35 improves the engagement of vehicle mating parts and substantially decreases severe/fatal injuries in any

- 5 real collision.
- E) minimizing the R&D work by reducing FEM calculations, crash tests and by saving material due to the arrangement of interengaging assembly in different operating planes.
- F) passenger protection for all collisions by a single construction, manufacturing, testing expenditure, assembly and material supply.
- 10 G) exploitation of the flange 21, 21T, 21h, 21x of vehicle body 20 provided with sound-proofing material 21.10 in Figs. 1, 17, 18 due to the sites to accommodate keys and the continuous stress curve. The enlargement of the flange to a limited extent neither impairs the overall stylish impression nor obstructs the passenger from ingress into or egress from the passenger compartment. Those edges (regions) of all post sections are defined
- 15 by the dotted lines "a1", "b1", "b2" and "c1".
- H) overall stylish impression. As substitutes of the bulky bolt ref. to U.S. Pat. No 3,819,228 small-size parts can be distributed in inconspicuous manner along the window-guide elements as well as flange, thus substantially ensuring the engagement of vehicular couple whilst lowering stress. Due to this feature it is possible to arrange the following
- 20 keys:
- 30, 32, 35, 37 to the respective flange 21 of vehicle body 20. In contrary to U.S. Pat. No. 3,819,228, this feature won't endanger passenger when stepping in or out, furthermore, more useful for passenger protection in side collision, particularly, according to collision types U1 and U2 in Fig. 13 as well as in front collision.
  - 25 - 15.2a, 15.2, 15.7 e.g. with screws M4 to the narrow window-guide element 6.3, 6.3B of upper door frame 8.17 to resolve the problem of the large, stiff contour groove ref. to DE-OS 2162071.
  - 33, 34, 36 to the respective window-guide elements 6, 6B and elements 6.7, 6.8 in engagement with the reinforced B-post section in two to three operating planes
  - 30 without obstructing the operation of the seat belt 26.1 in Fig. 15. The fact, that no contact is made during the opening operation of series-connected vehicle doors, is demonstrated by the trajectories of both outer points of the washer and of the door edges drawn with dotted lines.
  - 31 to the respective window-guide elements 6 and elements 6.6a in engagement with
  - 35 the reinforced A-post section.
- I) less stress to solve the problem of total deformation. By means of arrangement of interengaging assemblies of each vehicular couple in multi-operating planes and increase of vehicular couples such as vehicle door & vehicle roof 17, vehicle door & side rail 18, vehicle door & post section/s and vehicle door & vehicle body 20 more vehicle members
- 40 in compound construction are involved in energy absorption in different load cases in the event of any collision and/or rollover.
- In co-operation with DE 4342038 A1 the structural stiffness reaches the maximum. Beyond doubt, the advantage of keys 2.1, 5.6 & mating holes is due to the further exploitation of the very stiff impact beams 1, 7 to house the corresponding parts.
- 45 Because the other vehicular couples such as vehicle door & side rail and vehicle door & vehicle roof are not equipped with interengaging assemblies this *single* arrangement of one vehicular couple in mid region of door is insufficient in the event of any collision and/or rollover, therefore endangering the passengers in the following state of deformation

- intrusion of vehicle roof 17 into the vehicle body and of upper door frame 8.17, thus squashing the passengers and
- buckling of the upper portion of the A-post section, total deformation of upper door frame 8.17, buckling of vehicle roof 17 and buckling of side rails 18 in Fig. 8.

5 In order to avoid the above-mentioned state a number of holes or keys 30 to 37 is arranged to the flange 21 *above, below* of the impact beams 1, 7 and *therebetween*. When the *non-adjustable* rivets 5.6 of the door hinges in x-z operating plane are replaced by a number of interengaging assemblies 15.1, 15.2a, 15.4, 30, 31 in several operating planes, the total stress of the vehicular couples: A-post section & vehicle door  
10 along the z-axis is lower owing to stress distribution, thereby preventing, to a certain extent, the A-post section and vehicle door from total deformation and gap o in Fig. 8.

J) measures against passenger ejection and total deformation of the vehicle members, whereby vehicle doors are not or less deformed, in real accident ref. to problem cases E2 to E4, which can solely be solved by engagement of the following interengaging  
15 assemblies governed by permissible tolerances:

- holes & keys 15.3, 15.3a, 15.5a, 15.5 owing to U-shaped extension members 17.3, 18.3, whose deformation causes a constrained deformation of the series-connected vehicle doors, vehicle roof and side rails;
- holes & keys 32, 33, 34, 30, 15.2, 15.4a of the vehicular couple: vehicle door & B-  
20 post section in four operating planes; *and/or*
- hooks 15.6 & reinforcing rod 17.1d of both vehicular couples: series-connected vehicle doors & side rail and series-connected vehicle doors & vehicle roof, so that the deformation of the side rail and vehicle roof causes a constrained deformation of the series-connected vehicle doors; and

25 by *energy transmission* into the other vehicle side by means of transverse girders 17.2, 17.2b, 17.2c, 17.2d, 18.2 of vehicle roof, side rails and all post sections facing each other, thus distributing the energy thereto.

K) passenger protection by engagement of vehicle couples in rear collision. Door detachment [13] in rear collision occurred due to the lack of door hinges and  
30 interengaging assemblies. For the purpose of connection of vehicular members to each other the engagement of rear door 8B with the C-post section is improved by rigidly arranging

- element 6.5C, adapted to the outer door-contour and having holes to receive mating keys 37 in Figs. 14, 18, to the door frame of rear door; and

- keys 33, 34 to window-guide element 6B.

35 The features of vehicle door are, doubtless, suitable for tailgate door 8T, sliding side door, liftgate door cargo door, trunk cover 8x, hood 8h, series-connected doors, e.g. three vehicle doors with four post sections of large van.

## BRIEF DESCRIPTION OF THE DRAWINGS

A number of embodiments, other advantages and features of the present invention will be described in the accompanying drawings with reference to the xyz global coordinate system::

Fig. 1 is a side view of vehicle side, body, impact beams, keys, hooks, window-guides and window-guide elements (reinforcing elements).

Fig. 1A is a cross-sectional view of a vehicle door engaging with a roof and side rail ref. to DE-OS 2162071 in side collision.

Fig. 1B is a cross-sectional view of a vehicle door engaging with a side rail ref. to EP 0423465 A1 in side collision.

Fig. 2 is a side view of an U-shaped window-guide element, the position of keys 15.7, 15.8 and of an additional window-guide element 6.4, 6.4B.

Fig. 2A is a side view of an U-shaped window-guide element, the position of keys 15.7.

Fig. 3 is a perspective view of a front stiff door frame with both window-guides, both respective window-guide elements and interengaging assemblies of the 1st embodiment.

Fig. 3A is a cross-sectional view of a key equipped with an adjusting mechanism.

Fig. 4 is a perspective view of interengaging assembly hooks & reinforcing rod of the 2nd embodiment.

Fig. 4A is a cross-sectional view of the reinforcing rod and the mating hook equipped with an adjusting mechanism.

Fig. 5 illustrates a load case I in z-y plane in front collision of vehicle.

Fig. 6 illustrates a load case II in z-x plane in front collision.

Fig. 7 illustrates a load case III in x-y plane in front collision.

Fig. 8 is a state of total deformation of vehicle at displacement v in front collision.

Fig. 9 illustrates a load case IV in x-y plane in side collision of vehicle.

Fig. 10 illustrates a load case V in z-x plane in side collision.

Fig. 10A illustrates the mating parts of interengaging assemblies ref. to U.S. Pat. No 4,307,911 (DE 3103580 A1), both mating parts of a door lock, the general force  $F_1$  or  $S_1$  in the event of front or side collision and a highway column.

Fig. 11 is a view of a compression-coil spring on a lower spring seat.

Fig. 12 illustrates the projection of the end coil and spring seat in a plane, the test results and FEM data of an end coil rolling on the lower spring seat in dependence on load.

Fig. 13 illustrates four collision types U1 to U4 ref. to the research work of Institute of Vehicle Safety, a Dept. of German Insurers Association, and a highway column.

Fig. 14 is a perspective view of interengaging assemblies of the 3rd embodiment comprising a stiff front door frame having a single window-guide element and a stiff rear door frame having a single window-guide element to engage with the post sections and flange of vehicle body.

Fig. 15 is a cross-sectional view of the series-connected doors in engagement with the A-, B-post section and of the vehicle body along the line D-D in Fig. 14.

Fig. 16 is a side view of the series-connected stiff door frames without window pane in engagement with the B-post section according to arrow E in Fig. 14.

Fig. 17 is a perspective view of interengaging assemblies of the 4th embodiment comprising a stiff front door frame having a single window-guide element in engagement with the flange of vehicle body.

Fig. 18 is a side view of the flange of vehicle body provided with keys.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

In Fig. 3 the 1st embodiment consists of interengaging assemblies, whose keys are attached to two window-guide elements of vehicle door and whose mating receptacles to the A- and B-post section, vehicle roof and side rail.

- 5 In Fig. 4 the 2nd embodiment consists of an interengaging assembly, whose hooks are attached to two window-guide elements of each vehicle door and whose mating rod to the vehicle roof and all post sections. The rod serves to reinforce the vehicle roof and to aid positioning at the assembly thus cutting costs. However, this embodiment needs space, which is available in large cars, trucks and vans. This embodiment is suited for another vehicular couple: vehicle door/s & side rail.

10 In Figs. 14 to 16 the 3rd embodiment consists of interengaging assemblies, whose keys are attached to a window-guide element of each vehicle door 8, 8B and whose mating receptacles to the A-, B-post section and respective reinforcing elements 21.3, 21.3B of flange 21 of vehicle body 20. The keys 30 to 37 & holes can arbitrarily be attached to vehicle doors, post sections and vehicle body. After welding the extension member 23 to the inner region of B-post section the holes are machined.

The 4th embodiment consists of

- interengaging assemblies 30 & 6.5, 35 & 6.5B and other interengaging assemblies 32 & 6.9, 37 & 6.9B (6.9, 6.9B similar to 6.5), 37 & 6.5C in Fig. 14, 17,
- 20 – flange 21 of vehicle body 20 and the enlarged flange defined by the dotted lines "a1", "b1", "b2" and "c1" along the post sections to house the keys 30, 32, 35, 37 in Fig. 18,
- two vehicular couples such as flange 21 of vehicle body 20 & window-guide element 6 of front door 8 and flange 21 of vehicle body 20 & window-guide element 6B of rear door 8B and
- 25 – keys 30, 32, 35, 37 rigidly attached to the respective reinforcing elements 21.1 to 21.5, 21.1B to 21.5B of flange 21 of vehicle body 20. The welding of reinforcing elements to the flange facing to the vehicle doors has the advantage of using only a single element such as 21.4, 21.1B. Those elements can be arranged between both panels of vehicle body. The reinforcing element 21.5B is welded to the flange and rear wheel case. The
- 30 same reinforcing method can be employed to arrange a similar element 21.1 to the flange and the front wheel case.

According to the description of DE 4342038 A1 a stiff door frame of vehicle door can be assembled, without door girder and reinforcing elements, from at least two impact beams provided with interengaging assemblies and at least one window-guide element 6, 6B, 6.1, 6.2, 6.1B, 6.2B, 6.1a, 6.2a, 6.1aB, 6.2aB. As is customary, the window-guides 6.1, 6.2, 6.1B, 6.2B in Figs. 1 and 3 are made from U-shaped thin panel. As *reinforcing elements* the window-guide elements are of higher-grade tensile strength 6.1a, 6.2a, 6.1aB, 6.2aB to:

- reinforce the U-shaped window-guides of metal sheets,
- receive parts such as hooks, keys and/or holes and
- 40 – receive elements 6.5, 6.5B, 6.6a, 6.6b, 6.7a, 6.7b, 6.8, 6.9 (not drawn) as structural element with higher-grade tensile strength.

The following elements are fixedly attached

- 6.8, 6.9 to the front faces of both impact beams **1B**, **7B** and window-guide element **6B**,
- 6.6b, 6.7b to window-guide element 6 and impact beams 7 and
- 6.6a, 6.7a between both impact beams 1, 7 and window-guide element 6.

Both window-guide elements are replaceable by an U-shaped stiff window-guide element 6, **6B** in Figs. 2, 2A, 14 to 17. Less stiff elements 6.3, **6.3B** are normally made of panel. Alternately, very stiff window-guide element 6.3, **6.3B** serves to receive the window pane and keys 15.7.

Window-guide element 6, **6B** provided with window-guide element 6.3, **6.3B** in the door cavity in Fig. 2A have open ends. To maximize the stiffness of window-guide element 6, **6B** both ends are rigidly connected to each other by window-guide element 6.4, **6.4B** in the door cavity in Figs. 2, 14 to 17:

- after the window pane has been inserted, *or*
- by having flat profile in Figs. 14, 15, 17 for the purpose of receiving window pane 60, **60B** in Fig. 15. Later on, this window pane must be secured against falling down by protective parts.

The window-guide element 6.4, **6.4B** is useful for accommodation of keys 15.8. If extraneous weight is not that important for heavy cars, trucks and vans, the following goals for independent parts are applicable:

- the window-guide element fastened to the impact beams serving as members of door frame to receive keys and
- the window-guides of panel to guide and receive the window pane.

To engage with the mating receptacles the following keys are attached:

- 15.1, 15.2, 15.2a, 15.3, 15.3a, 15.4, 15.4a, 15.5 and 15.5a along the vehicle roof, side rail and post sections,
- 15.3, 15.3a and/or 15.5, 15.5a to the *common* post section of the series-connected vehicle doors e.g. *B- and C- post section* of 6-door vans,
- 30 and 31 to the A-post section,
- 33, 34, 35 and 36 to the *common* post section of the series-connected vehicle doors,
- 33 and 34 to the C-post section,
- 15.7 replaced by at least one key 15.2, 15.2a, 15.4, 15.4a, 30 to 37 along the vehicle roof,
- 15.8 replaced by at least one key 15.2, 15.2a, 15.4, 15.4a, 30 to 37 along the side rail.

Owing to this design keys 15.1 can generally be attached to the post section having door hinges.

In the following embodiments in Figs. 3, 4, 14 to 18 the connection of all series-connected doors with vehicle roof 17, vehicle body 20, vehicle floor fastened to two side rails 18 facing each other and with the respective post sections in any collision and/or rollover is ensured by engagement of the following keys 15.1 to 15.5a, 30 to 37 with holes and/or of the following hooks 15.6 with reinforcing rod 17.1d:

- key 15.1, bolted to a reinforcing element of the L-shaped A-post section, with the oblong hole of window-guide element 6.1a. This A-post section is welded to reinforcing panel 17.1c arranged along the vehicle roof and to transverse girder 17.2d of both facing A-post sections of both vehicle sides. This feature is applicable for window-guide element 6.2a, 6.1aB, 6.2aB in association with the B- or C-post section.
- key 15.2a, bolted to stiff element 6.11 of window-guide element 6.1a, with the oblong hole of reinforcing panel 17.1 arranged along the vehicle roof. This panel is welded to reinforcing plate 17.2a of the L-shaped A-post section and to transverse girders 17.2,

17.2b of both facing A-post sections. To cut costs the reinforcing plate 17.2a can act as transverse girder by eliminating parts 17.2, 17.2b. These features are applicable for window-guide element 6.2a, 6.1aB, 6.2aB in association with the B- or C-post section.

- 5     - key 15.2, bolted to window-guide element 6.2a, with the hole of reinforcing panel 17.1a arranged along the vehicle roof. This feature is applicable for engagement of key 15.2 bolted to window-guide element 6.1a, 6.1aB, 6.2aB with the hole.
- 10    - key 15.3 and key 15.3a, bolted to the legs of U-shaped extension member 17.3, with the apertures of window-guide elements 6.2a, 6.1aB. As connection element between the B-post section and the vehicle roof this U-shaped extension member in the B-post section is welded to reinforcing panel 17.1b arranged along the vehicle roof and to transverse girder 17.2c of both facing B-post sections of both vehicle sides.
- 15    - key 15.4, bolted to the reinforcing plate of reinforcing panel 18.1 arranged along the side rail, with the hole of window-guide element 6.1a. This feature is applicable for window-guide elements 6.2a, 6.1aB, 6.2aB.
- 20    - key 15.4a such as pin e.g. ref. to DIN660, fastened to the reinforcing plate of reinforcing panel 18.1a arranged along the side rail, with the hole of window-guide element 6.2a.
- 25    - key 15.2a in x-y operating plane as substitute for key 15.4, 15.4a or 15.8.
- 30    - key 15.5 and key 15.5a, bolted to the legs of U-shaped extension member 18.3, with the apertures of window-guide elements 6.2a, 6.1aB. As connection element between the B-post section and the vehicle floor this U-shaped extension member in the B-post section is welded to reinforcing panel 18.1b arranged along the vehicle floor and to transverse girder 18.2 of both facing B-post sections of both vehicle sides. The belt case 26 can be housed in U-shaped extension member 18.3.
- 35    - hooks 15.6, bolted to window-guide elements 6.1a, 6.2a, 6.1aB, 6.2aB, with the reinforcing rod 17.1d arranged along the vehicle roof or side rail in Fig. 4. This rod is welded to transverse girders 17.2e, 17.2f, 17.2g of both A-, B- and C-post sections.
- 40    - keys 30, 32, 35, 37, bolted to the respective reinforcing elements 21.3, 21.5, 21.3B, 21.5B of the bottom flange of vehicle body 20 in Figs. 14 to 18, with the corresponding holes of housings 6.5, 6.5B, auxiliary element 6.5C which are rigidly attached to the respective window-guide elements 6, 6B and the respective elements 6.6b, 6.7b, 6.8, 6.9 (not drawn because of the similarity to 6.7b).
- 45    - keys 30, 32, 35, 37, bolted to the respective reinforcing elements 21.1, 21.4, 21.1B, 21.4B of the top flange 21 of vehicle body 20, with the corresponding holes of housings 6.5, 6.5B, auxiliary element 6.5C which are rigidly attached to the respective window-guide elements 6, 6B.
- 50    - keys 30, 35, bolted to the respective reinforcing elements 21.2, 21.2B, which at halfway up location are fixed to the post-section-flange 21 of vehicle body 20, with the corresponding holes of housings 6.5, 6.5B which are rigidly attached to the respective window-guide elements 6, 6B and the respective impact beams 1, 1B.
- 55    - keys 31, bolted to element 6.6a of window-guide element 6, with the holes of (machined in) the reinforced A-post section in Figs. 14 to 16.
- 60    - keys 36, bolted to element 6.8 of window-guide element 6B, with the respective holes of the B-post section reinforced by extension member 23.
- 65    - keys 33, bolted to window-guide element 6, with the respective holes in the reinforced B-post section. Similarly, the keys 33 can be attached to window-guide element 6B and the respective holes of the reinforced C-post section. In Fig. 16 a washer 15.13 with radial teeth serves as part of key 33 to improve the engagement with the inner region of the reinforced B-post section in any collision and/or rollover. As an integral part of a screw ref. to DIN 931 Form Z the washer won't become loose on assembly.

- keys 34, bolted to element 6.7a of window-guide element 6, with the respective holes of the reinforced B-post section. Similarly, the keys 3e can be attached to element 6.9 of window-guide element 6B and the respective holes of the reinforced C-post section.

5 It is possible to arrange

- several pairs of keys 15.3, 15.5 to the legs of U-shaped extension member 17.3, 18.3 and
- several keys 30, 32, 35, 37 with the same feature in the enlarged flange 21 of vehicle body 20 defined by the dotted lines "a1", "b1", "b2" and "c1" in Fig. 18.

10 By applying the associative rule for the arrangement of each interengaging assembly the attachment of key and hole to the corresponding parts is reversible.

By welding a reinforcing plate to the surface of the site of part a structural reinforcement is achieved. If extraneous weight is insignificant for heavy vehicle like truck or van, replace reinforcing panel by beam or beam-rod.

15 Costs can be cut by using mechanical connecting parts, particularly standard parts like washer ref. to DIN125, hexagon socket head screw ref. to DIN912 etc. This is exemplified by key 15.4a as rivet ref. to DIN660. With the exception of 15.4a each key 15.1 to 15.5a, 30 to 37 comprises a screw 15.14, a sleeve 15.11, a number of washers built into one spacer 15.12 and a washer with a large exterior diameter 15.13 illustrated in Figs. 3A, 14 to 18.

20 Despite larger tolerances the most inexpensive key 15.4a in association with the other keys 15.1 to 15.5a is suited for engagement with the respective holes. However, for perfect interengagement at low cost by limited use of the interengaging assemblies, the provision with keys 15.1 to 15.8, 30 to 37 without key 15.4a is ultimately necessary.

In order to ensure the engagement of key with mating hole a clearance in Figs. 3A, 14 to 18 must be preserved by:

- 25
- correcting the length of spacer l by removing or adding several washers and/or
  - assembling a sleeve with exterior diameter d, washer with exterior diameter D and/or spacer with diameter  $d_R$  chosen from the stock of the sleeves, washers and/or spacers with different diameters.

30 Each hook 15.6 in Figs. 4 and 4A comprises a hook 15.20 with interior diameter  $d_1$  and gap  $s_1$  smaller than  $d_1$ , a screw 15.21, a number of washers built into one spacer 15.22, a coil-spring washer 15.24 and a nut 15.25. The symbols  $s_1$ ,  $d_1$  and  $d_2$  are indicated in Fig. 4A. In order to ensure perfect engagement of the hooks with reinforcing rod 17.1d having diameter  $d_2$  smaller than  $s_1$ , small tolerance zones in Fig. 4A must be preserved by:

- 35
- assembling a hook with gap  $s_1$  chosen from the stock of the hooks with different gaps;
  - assembling a rod with diameter  $d_2$  chosen from the stock of the reinforcing rods with different diameters;
  - correcting the distance  $l_1$  by removing or adding several washers of spacer; and/or
  - positioning the centres of the hook hole and the reinforcing rod out of alignment.

40 Although the present invention has been described and illustrated in detail, it is clearly understood that the terminology used is intended to describe rather than limit. Many more objects, embodiments, features and variations of the present invention are possible in light of the above-mentioned teachings. Therefore, within the spirit and scope of the appended claims, the present invention may be practised otherwise than as specifically described and illustrated.